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ROSS LAKE, GLADWIN COUNTY, MICHIGAN

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center
Michigan Department of Natural Resources
Michigan National Guard

February 1975

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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REPORT

ON

ROSS LAKE

GLADWIN COUNTY

MICHIGAN

EPA REGION V

WORKING PAPER No. 209

WITH THE COOPERATION OF THE

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

AND THE

MICHIGAN NATIONAL GUARD

FEBRUARY, 1975

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Michigan Department of Natural Resources for professional involvement and to the Michigan National Guard for conducting the tributary sampling phase of the Survey.

A. Gene Gazlay, former Director, and David H. Jenkins, Acting Director, Michigan Department of Natural Resources; and Carlos Fetterolf, Chief Environmental Scientist, and Dennis Tierney, Aquatic Biologist, Bureau of Water Management, Department of Natural Resources, provided invaluable lake documentation and counsel during the course of the Survey. John Vogt, Chief of the Bureau of Environmental Health, Michigan Department of Public Health, and his staff were most helpful in identfying point sources and soliciting municipal participation in the Survey.

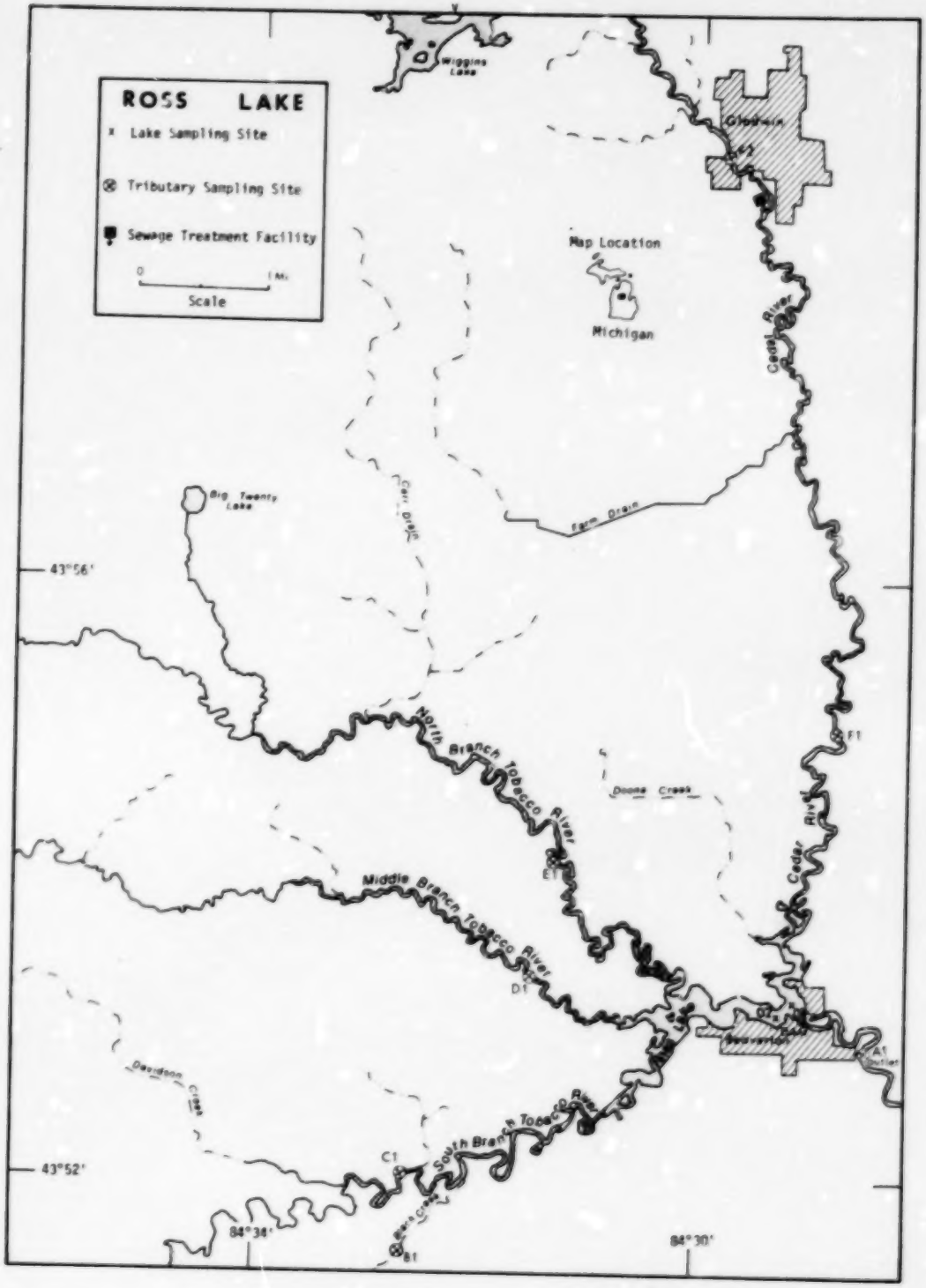
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MICHIGAN

LAKE NAME	COUNTY
Allegan Res.	Allegan
Barton	Kalamazoo
Belleville	Wayne
Betsie	Benzie
Brighton	Livingston
Caro Res.	Tuscola
Charlevoix	Charlevoix
Chemung	Livingston
Constantine Res.	St. Joseph
Crystal	Montcalm
Deer	Marquette
Ford	Washtenaw
Fremont	Newago
Higgins	Roscommon
Holloway Res.	Genesee, Lapeer
Houghton	Roscommon
Jordon	Ionia, Barry
Kent	Oakland
Long	St. Joseph
Macatawa	Ottawa
Manistee	Manistee
Mona	Muskegon
Muskegon	Muskegon
Pentwater	Oceana
Pere Marquette	Mason
Portage	Houghton
Randall	Branch
Rogers Pond	Mecosta
Ross	Gladwin
St. Louis Res.	Gratiot
Sanford	Midland
Strawberry	Livingston
Thompson	Livingston
Thornapple	Barry
Union	Branch
White	Muskegon


ROSS LAKE
Lake Sampling Site
Tributary Sampling Site
Sewage Treatment Facility
0
1 Mi.
Scale
Wiggins Lake
Gladwin
Map Location
Michigan
Cedar River
Big Twenty Lake
Farm Drain
43°56'
North Branch Tobacco River
Doone Creek
F1
E1
Middle Branch Tobacco River
D1
Cedar River
Sewerton
A1
Outlet
Davidson Creek
South Branch Tobacco River
C1
43°52'
84°34'
84°30'
B1

ROSS LAKE

STORET NO. 2673

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Ross Lake is eutrophic. Of the 35 Michigan lakes sampled in November when essentially all were well-mixed, 13 had less mean total phosphorus, 14 had less mean dissolved phosphorus, and 14 had less mean inorganic nitrogen; of all 41 Michigan lakes sampled, 17 had less mean chlorophyll a, but only four had less mean Secchi disc transparency*.

Survey limnologists indicated that the water was very turbid with moderate algal blooms occurring during the June and September sampling visits.

B. Rate-Limiting Nutrient:

There was a significant nutrient loss in the algal assay sample, and the results are not indicative of conditions in the lake at the time the sample was collected. However, the lake data indicate that nitrogen was limiting in June and September, and phosphorus was limiting in November.

C. Nutrient Controllability:

1. Point sources--During the sampling year, Ross Lake received a total phosphorus load at a rate more than five times

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* See Appendix A.

the rate proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate (see page 12). However, the mean hydraulic retention time of Ross Lake is a very short two days; and, with such "flow-through" conditions, it is very unlikely that Vollenweider's model is applicable.

It is calculated that the City of Gladwin contributed about 16% of the total phosphorus load to Ross Lake during the sampling year. While provision of 85% phosphorus removal at this source would only reduce the loading rate to about 14.8 $g/m^2/yr$, if additional reduction of phosphorus from "non-point" sources can be achieved, it is likely that the incidence and severity of nuisance algal blooms in Ross Lake would be reduced (see below).

2. Non-point sources (see page 12)--During the sampling year, the phosphorus exports of the South and Middle Branches of the Tobacco River were quite high as compared to the North Branch. Particularly in the case of the South Branch, it appears that point sources beyond the 25-mile limit of the Survey* may be involved (note that the export N/P ratio of this stream is about 14/1, whereas the export N/P ratio of the North Branch is 32/1.

* See Working Paper No. 1, "Survey Methods, 1972".

Whatever the source of the phosphorus input to the South Branch, it appears that significant improvement in the trophic condition of Ross Lake will require at least some reduction of this load.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 294 acres.
2. Mean depth: 5 feet.
3. Maximum depth: 15 feet.
4. Volume: 1,470 acre/feet.
5. Mean hydraulic retention time: 2 days

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
S. Branch, Tobacco River	157.0 mi^2	113.3 cfs
Middle Branch, Tobacco River	34.5 mi^2	31.5 cfs
N. Branch, Tobacco River	73.7 mi^2	75.1 cfs
Cedar River	121.0 mi^2	101.5 cfs
Minor tributaries & immediate drainage -	100.3 mi^2	36.8 cfs
Totals	486.5 mi^2	358.2 cfs

2. Outlet -

Tobacco River	487.0 mi^2**	358.2 cfs

C. Precipitation***:

1. Year of sampling: 31.8 inches.
2. Mean annual: 33.1 inches.

† Fetterolf, 1973.
* Drainage areas are accurate within ±5%; mean daily flows for 74% of the sampling sites are accurate within ±25% and the remaining sites up to ±40%; and mean monthly flows, normalized mean monthly flows, and mean annual flows are slightly more accurate than mean daily flows.
** Includes area of lake.
*** See Working Paper No. 1, "Survey Methods, 1972".

III. LAKE WATER QUALITY SUMMARY

Ross Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two stations on the lake and from a number of depths at each station (see map, page v). During each visit a single depth-integrated (near bottom to surface) sample was composited from the two stations for phytoplankton identification and enumeration; and during the second visit, a single five-gallon depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 10 feet at station 1 and 6 feet at station 2.

The results obtained are presented in full in Appendix C, and the data for the fall sampling period, when the lake essentially was well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix C.

A. Physical and chemical characteristics:

Parameter	Minimum	Mean	Median	Maximum
		FALL VALUES (11/14/72)		
Temperature (Cent.)	3.7	3.9	3.9	4.2
Dissolved oxygen (mg/l)	10.8	11.2	11.2	11.6
Conductivity (μmhos)	430	455	445	500
pH (units)	8.0	8.0	8.0	8.1
Alkalinity (mg/l)	199	213	213	226
Total P (mg/l)	0.032	0.034	0.034	0.035
Dissolved P (mg/l)	0.020	0.021	0.022	0.022
$NO_2 + NO_3$ (mg/l)	0.300	0.377	0.380	0.450
Ammonia (mg/l)	0.070	0.082	0.085	0.090
		ALL VALUES		
Secchi disc (inches)	29	35	31	48

B. Biological characteristics:

1. Phytoplankton* -

Sampling Date	Dominant Genera	Number per ml
09/20/72	1. Dinobryon	1,121
	2. Flagellates	850
	3. Cryptomonas	615
	4. Melosira	307
	5. Fragilaria	271
	Other genera	670
	Total	3,834
11/14/72	1. Flagellates	187
	2. Navicula	163
	3. Cymbella	151
	4. Achnanthes	139
	5. Dinobryon	84
	Other genera	494
	Total	1,218

* The June sample was lost in shipment.

2. Chlorophyll a -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll a (µg/l)
06/14/72	01	19.7
	02	16.2
09/20/72	01	13.5
	02	11.3
11/14/72	01	0.8
	02	0.8

C. Limiting Nutrient Study:

There was a loss of 59% of the dissolved phosphorus in the assay sample between the time of collection and the beginning of the assay, and the assay results are not representative of conditions in the lake at the time the sample was taken.

The lake data indicate nitrogen limitation in June and September (N/P ratios = 9/1 and less) but phosphorus limitation in November (N/P = 22/1).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Michigan National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of May, June, and July when two samples were collected. Sampling was begun in October, 1972, and was completed in September, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Michigan District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the means of the nutrient loads, in $lbs/mi^2/year$, at stations C-1, D-1, and E-1 and multiplying the means by the ZZ area in mi^2.

The operator of the Gladwin wastewater treatment plant provided monthly effluent samples and corresponding flow data.

In the following tables, the nutrient loads given for the Cedar River are those measured at station F-1 minus the Gladwin loads.

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* See Working Paper No. 1.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (mgd)	Receiving Water
Gladwin	2,071	prim. clarifier	0.682	Cedar River

2. Known industrial - None

* Kooistra, 1973.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
S. Branch, Tobacco River	19,690	44.1
Middle Br., Tobacco River	2,850	6.4
N. Branch, Tobacco River	4,490	10.1
Cedar River	1,570	3.5
b. Minor tributaries & immediate drainage (non-point load) -	8,990	20.1
c. Known municipal STP's -		
Gladwin	7,010	15.7
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	50	0.1
Total	44,650	100.0

2. Outputs -

Lake outlet - Tobacco River 38,220

3. Net annual P accumulation - 6,430 pounds

* See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
S. Branch, Tobacco River	275,750	28.7
Middle Br., Tobacco River	83,000	8.6
N. Branch, Tobacco River	143,300	14.9
Cedar River	225,680	23.5
b. Minor tributaries & immediate drainage (non-point load) -	204,140	21.3
c. Known municipal STP's -		
Gladwin	25,600	2.7
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	2,830	0.3
Total	960,300	100.0

2. Outputs -

Lake outlet - Tobacco River 884,970

3. Net annual N accumulation - 75,330 pounds

* See Working Paper No. 1.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs P/mi^2/yr	lbs N/mi^2/yr
S. Branch, Tobacco River	125	1,756
Middle Br., Tobacco River	83	2,406
N. Branch, Tobacco River	61	1,944
Cedar River	13	1,865

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with very short hydraulic retention times.

Units	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
lbs/acre/yr	151.9	21.9	3,266.3	256.2
grams/m^2/yr	17.02	2.45	366.1	28.7

Vollenweider loading rates for phosphorus (g/m^2/yr) based on mean depth and mean hydraulic retention time of Ross Lake:

"Dangerous" (eutrophic rate)	3.10
"Permissible" (oligotrophic rate)	1.55

V. LITERATURE REVIEWED

Fetterolf, Carlos, 1973. Personal communication (lake morphometry). MI Dept. of Nat. Resources, Lansing.

Kooistra, Ronald D., 1973. Wastewater treatment plant questionnaire. MI Dept. of Nat. Resources, Lansing.

Vollenweider, Richard A. (in press). Input-output models. Schweiz. Z. Hydrol.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES MEAN TOTAL P	FALL VALUES MEAN DISS P	FALL VALUES MEAN INORG N	ALL VALUES 500-MEAN SEC	ALL VALUES MEAN CHLORA	ALL VALUES 15-MIN DO
2640	HOLLOWAY RESERVOIR	0.062	0.043	1.461	439.375	10.674	9.200
2641	CARO RESERVOIR	0.117	0.022	3.835	473.000	11.967	9.500
2642	BOARDMAN HYDRO POND	0.006	0.005	0.358	363.500	1.267	6.600
2643	ALLEGAN LAKE	0.123	0.057	1.168	470.222	20.311	12.600
2646	BARTON LAKE	0.121	0.046	1.489	456.167	27.800	14.850
2649	BELLEVILLE LAKE	0.118	0.048	1.420	465.250	28.262	8.200
2610	BETSIE LAKE	0.025	0.006	0.273	461.667	4.567	7.400
2613	BRIGHTON LAKE	0.109	0.073	1.015	456.000	44.233	7.500
2617	LAKE CHARLEVOIX	0.007	0.006	0.230	351.250	3.008	9.240
2618	LAKE CHEMUNG	0.044	0.014	0.132	404.333	13.483	14.600
2621	CONSTANTINE RESERVOIR	0.027	0.008	0.910	456.167	39.317	7.500
2629	FORD LAKE	0.105	0.058	1.536	456.167	14.733	14.000
2631	FREMONT LAKE	0.372	0.342	1.406	441.667	28.500	14.600
2640	JORDAN LAKE	0.160	0.144	1.998	427.667	20.517	14.900
2643	KENT LAKE	0.040	0.015	0.417	455.000	33.944	13.000
2648	LAKE MACATAWA	0.197	0.120	2.358	477.600	25.600	12.200
2649	MANISTEE LAKE	0.018	0.010	0.304	491.333	6.317	11.360
2659	MUSKEGON LAKE	0.087	0.043	0.469	436.444	9.511	14.800
2665	PENTWATER LAKE	0.027	0.017	0.496	430.667	16.083	14.800
2671	RANDALL LAKE	0.246	0.183	0.816	457.333	27.217	8.020
2672	ROGERS POND	0.026	0.015	0.183	436.500	8.133	9.600
2673	RUSS RESERVOIR	0.034	0.021	0.460	465.333	10.383	8.200
2674	SANFORD LAKE	0.016	0.008	0.307	458.750	13.791	8.300
2683	THORNAPPLE LAKE	0.042	0.032	1.737	442.833	14.650	10.800
2685	UNION LAKE	0.083	0.064	1.252	455.500	15.667	8.200
2688	WHITE LAKE	0.027	0.019	0.367	417.778	9.211	13.400
2691	MONA LAKE	0.307	0.241	0.963	451.667	27.783	14.100
2692	LONG LAKE	0.163	0.148	0.744	410.400	10.067	13.600

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES MEAN TOTAL P	FALL VALUES MEAN DISS P	FALL VALUES MEAN INORG N	ALL VALUES 530-MEAN SEC	ALL VALUES MEAN CHLORA	ALL VALUES 15-MIN DO
2693	ST LOUIS RESERVOIR	0.134	0.093	1.227	462.667	5.583	8.420
2694	CRYSTAL LAKE	0.009	0.006	0.164	380.000	2.986	13.000
2695	HIGGINS LAKE	0.007	0.005	0.058	268.500	1.043	9.400
2696	HOUGHTON LAKE	0.018	0.008	0.136	420.833	9.217	8.200
2697	THOMPSON LAKE	0.043	0.029	0.436	407.889	11.967	14.800
2698	PERE MARQUETTE LAKE	0.032	0.024	0.346	448.667	11.833	8.600
2699	STRAWBERRY LAKE	0.069	0.050	0.567	419.800	11.117	13.600

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500- MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15- MIN DO	INDEX NO
2680	HALLOWAY RESERVOIR	46 (10)	43 (15)	17 (6)	57 (20)	60 (21)	63 (22)	266
2681	CARO RESERVOIR	29 (13)	54 (19)	0 (0)	3 (1)	49 (17)	54 (19)	189
2682	BOAHOMAN HYDRO POND	97 (34)	97 (34)	69 (24)	91 (32)	94 (33)	97 (34)	545
2683	ALLEGAN LAKE	20 (7)	31 (11)	31 (11)	6 (2)	29 (10)	40 (14)	157
2686	BANTON LAKE	23 (8)	20 (7)	14 (5)	29 (9)	14 (5)	3 (1)	103
2689	BELLEVILLE LAKE	26 (9)	37 (13)	20 (7)	11 (4)	11 (4)	79 (26)	164
2610	BETSIE LAKE	77 (27)	77 (27)	80 (28)	17 (6)	86 (30)	94 (33)	431
2613	BRIGHTON LAKE	31 (11)	23 (8)	34 (12)	34 (12)	0 (0)	90 (31)	212
2617	LAKE CHARLEVOIX	91 (32)	91 (32)	83 (29)	94 (33)	89 (31)	60 (21)	508
2618	LAKE CHEMUNG	49 (17)	71 (25)	94 (33)	86 (30)	46 (16)	11 (2)	357
2621	CONSTANTINE RESERVOIR	71 (25)	83 (29)	40 (14)	29 (9)	3 (1)	90 (31)	316
2629	FORD LAKE	34 (12)	29 (10)	11 (4)	29 (9)	37 (13)	23 (8)	163
2631	FREMONT LAKE	0 (0)	0 (0)	23 (8)	54 (19)	9 (3)	11 (2)	97
2640	JORDAN LAKE	11 (4)	11 (4)	6 (2)	69 (24)	26 (9)	0 (0)	123
2643	KENT LAKE	57 (20)	69 (24)	63 (22)	40 (14)	6 (2)	36 (12)	271
2648	LAKE MACATAWA	9 (3)	14 (5)	3 (1)	0 (0)	23 (8)	43 (15)	92
2649	MANISTEE LAKE	80 (28)	74 (26)	77 (27)	46 (16)	80 (28)	46 (16)	403
2659	MUSKEGON LAKE	37 (13)	40 (14)	54 (19)	60 (21)	69 (24)	11 (2)	271
2665	PENTWATER LAKE	69 (24)	63 (22)	51 (18)	66 (23)	31 (11)	11 (2)	291
2671	RANDALL LAKE	6 (2)	6 (2)	43 (15)	23 (8)	20 (7)	86 (30)	184
2672	ROGERS POND	74 (26)	66 (23)	86 (30)	63 (22)	77 (27)	51 (18)	417
2673	RUSS RESERVOIR	60 (21)	57 (20)	57 (20)	9 (3)	63 (22)	79 (28)	325
2674	SANFORD LAKE	86 (30)	80 (28)	74 (26)	20 (7)	43 (15)	71 (25)	374
2683	THORNAPPLE LAKE	54 (19)	46 (16)	9 (3)	51 (18)	40 (14)	49 (17)	249
2685	UNION LAKE	40 (14)	26 (9)	26 (9)	37 (13)	34 (12)	79 (28)	242
2688	WHITE LAKE	66 (23)	60 (21)	66 (23)	80 (28)	74 (26)	31 (11)	377
2691	MONA LAKE	3 (1)	3 (1)	37 (13)	43 (15)	17 (6)	20 (7)	123
2692	LONG LAKE	14 (5)	9 (3)	46 (16)	77 (27)	66 (23)	27 (9)	239

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500-MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15-MIN DO	INDEX NO
2693	ST LOUIS RESERVOIR	17 (6)	17 (6)	29 (10)	14 (5)	83 (29)	69 (24)	229
2694	CRYSTAL LAKE	89 (31)	89 (31)	89 (31)	89 (31)	91 (32)	36 (12)	483
2695	HIGGINS LAKE	94 (33)	94 (33)	97 (34)	97 (34)	97 (34)	57 (20)	536
2696	HOUGHTON LAKE	83 (29)	86 (30)	91 (32)	71 (25)	71 (25)	79 (26)	481
2697	THOMPSON LAKE	51 (18)	49 (17)	60 (21)	83 (29)	51 (18)	11 (2)	305
2698	PERE MARQUETTE LAKE	63 (22)	51 (18)	71 (25)	49 (17)	54 (19)	66 (23)	356
2699	STRAWBERRY LAKE	43 (15)	34 (12)	49 (17)	74 (26)	57 (20)	27 (9)	284

APPENDIX B

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2673 ROSS LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 487.00

NORMALIZED FLOWS(CFS)

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2673A1	487.00	290.00	344.00	672.00	746.00	423.00	284.00	260.00	198.00	212.00	255.00	300.00	316.00	358.15
2673C1	157.00	92.00	108.00	212.00	237.00	136.00	93.00	81.00	62.00	66.00	80.00	94.00	99.00	113.28
2673D1	34.50	25.00	30.00	59.00	66.00	38.00	26.00	23.00	17.00	18.00	22.00	26.00	28.00	31.48
2673E1	73.70	60.00	71.00	138.00	157.00	92.00	64.00	50.00	42.00	44.00	54.00	64.00	66.00	75.12
2673F1	121.00	82.00	96.00	187.00	211.00	126.00	88.00	66.00	56.00	60.00	72.00	86.00	89.00	101.52
2673ZZ	101.00	31.00	39.00	76.00	75.00	31.00	13.00	40.00	21.00	24.00	27.00	30.00	34.00	36.75

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 487.00
SUM OF SUB-DRAINAGE AREAS = 487.20

TOTAL FLOW IN = 4300.00
TOTAL FLOW OUT = 4300.00

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2673A1	10	72	365.00	29	535.00				
	11	72	393.00						
	12	72	301.00	2	268.00				
	1	73	819.00	6	560.00				
	2	73	412.00	3	958.00				
	3	73	1105.00	3	484.00				
	4	73	642.00	7	673.00				
	5	73	684.00	2	1090.00	10	907.00		
	6	73	469.00	3	580.00	4	959.00	18	301.00
	7	73	265.00	23	206.00	28	366.00		
	8	73	261.00	28	195.00				
	9	73	166.00	28	209.00				
2673C1	10	72	113.00	29	166.00				
	11	72	122.00						
	12	72	93.00	2	83.00				
	1	73	262.00	6	179.00				
	2	73	128.00	3	297.00				
	3	73	354.00	3	155.00				
	4	73	205.00	7	215.00				
	5	73	219.00	2	349.00	10	290.00		
	6	73	138.00	3	221.00	4	329.00	18	84.00
	7	73	80.00	23	63.00	28	86.00		
	8	73	66.00	28	58.00				
	9	73	58.00	28	66.00				

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2673 ROSS LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
267301	10	72	31.00	29	46.00				
	11	72	34.00						
	12	72	27.00	2	24.00				
	1	73	70.00	6	48.00				
	2	73	36.00	3	83.00				
	3	73	97.00	3	43.00				
	4	73	56.00	7	59.00				
	5	73	62.00	2	98.00	10	82.00		
	6	73	39.00	3	62.00	4	93.00	18	24.00
	7	73	22.00	23	18.00	28	28.00		
	8	73	24.00	28	16.00				
	9	73	16.00	28	18.00				
2673E1	10	72	77.00	29	112.00				
	11	72	83.00						
	12	72	63.00	2	56.00				
	1	73	172.00	6	115.00				
	2	73	87.00	3	201.00				
	3	73	232.00	3	102.00				
	4	73	135.00	7	141.00				
	5	73	150.00	2	240.00	10	200.00		
	6	73	96.00	3	154.00	4	229.00	18	59.00
	7	73	49.00	23	39.00	28	62.00		
	8	73	57.00	28	40.00				
	9	73	38.00	28	44.00				
2673F1	10	72	102.00	29	150.00				
	11	72	114.00						
	12	72	84.00	2	75.00				
	1	73	229.00	6	157.00				
	2	73	115.00	3	268.00				
	3	73	309.00	3	136.00				
	4	73	180.00	7	188.00				
	5	73	295.00	2	327.00	10	272.00		
	6	73	130.00	3	207.00	4	309.00	18	79.00
	7	73	65.00	23	52.00	28	71.00		
	8	73	77.00	28	54.00				
	9	73	52.00	28	60.00				
2673Z7	10	72	42.00						
	11	72	40.00						
	12	72	34.00						
	1	73	86.00						
	2	73	46.00						
	3	73	113.00						
	4	73	66.00						
	5	73	48.00						
	6	73	66.00						
	7	73	49.00						
	8	73	37.00						
	9	73	25.00						

APPENDIX C

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/02/04

261301
43 48 00.0 084 30 00.0
ROSS RESERVOIR
26 MICHIGAN

11EPALES
5

2111202
0015 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/14	13 35	0000	19.4	10.0	48	490	8.27	193	0.020	0.010K	0.034	0.015
	13 35	0010	16.8	6.8		450	8.00	195	0.070	0.070	0.044	0.020
72/09/20	09 50	0000			32	595	7.90	197	0.100	0.060	0.029	0.018
	09 50	0004	18.9	8.4		590	7.90	196	0.100	0.060	0.035	0.020
	09 50	0008	18.8	8.4		595	7.90	200	0.110	0.070	0.034	0.019
72/11/14	15 30	0000			39	430	8.00	199	0.300	0.070	0.032	0.020
	15 30	0006	4.2	11.6		430	8.10	199	0.310	0.080	0.035	0.022

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/14	13 35	0000	19.7J
72/09/20	09 50	0000	13.5J
72/11/14	15 30	0000	9.8J

J VALUE KNOWN TO BE IN ERROR

K VALUE KNOWN TO BE LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

267302
43 48 00.0 084 30 00.0
ROSS RESERVOIR
26 MICHIGAN

11EPALES 2111202
5 0008 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/14	14 00	0000	19.1	11.2	30	520	8.30	199	0.040	0.010K	0.046	0.020
	14 00	0006	16.3	7.7								
72/09/20	10 00	0000			30	640	7.85	203	0.200	0.060	0.046	0.031
	10 00	0004	18.5	8.2		640	7.85	203	0.200	0.060	0.049	0.034
72/11/14	15 45	0000			29	500	8.00	226	0.450	0.090	0.034	0.022
	15 45	0005	3.7	10.8		460	8.10	226	0.450	0.090	0.035	0.022

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/14	14 00	0000	16.2J
72/09/20	10 00	0000	11.3J
72/11/14	15 45	0000	0.8J

K VALUE KNOWN TO BE LESS THAN INDICATED

J VALUE KNOWN TO BE IN ERROR

APPENDIX D

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 75/02/04

2673A1 L52673A1
43 53 00.0 084 13 30.0
TOBACCO RIVER
26 GLADWIN CO
O/ROSS LAKE (RESERVOIR)
GLIDDEN RD BRDG
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	10 40		0.420	2.950	0.294	0.021	0.046
72/12/02	10 00		0.195	0.830	0.022	0.017	0.036
73/01/06	10 00		0.440	0.610	0.063	0.019	0.040
73/02/03	09 00		0.320	1.690	0.140	0.020	0.035
73/03/03	10 30		0.280	0.300	0.063	0.023	0.040
73/04/07	08 35		0.220	0.650	0.036	0.016	0.040
73/05/02			0.350	1.760	0.055	0.010	0.060
73/05/10	18 00		0.273	0.780	0.029	0.017	0.065
73/06/04	13 00		0.440	1.000	0.370	0.015	0.075
73/06/18	09 50		0.087	0.620	0.054	0.023	0.055
73/07/23	12 10		0.011	0.880	0.034	0.008	0.045
73/07/28	10 00		0.058	1.200	0.056	0.022	0.070
73/08/28	10 00		0.138	0.570	0.105	0.031	0.095
73/09/28	10 30		0.044	0.280	0.031	0.018	0.045

STORET RETRIEVAL DATE 75/02/04

267391 LS267391
43 51 30.0 084 32 30.0
BLACK CREEK
26 GLADWIN CO
T/ROSS LAKE (RESERVOIR)
DALE RD XING P
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	10 05		0.250	2.230	0.240	0.009	0.029
72/12/02	08 55		0.034	2.100	0.063	0.005K	0.011
73/01/06	09 30		0.100	1.320	0.090	0.009	0.021
73/02/03	09 20		0.062	1.540	0.066	0.006	0.020
73/03/03	09 30		0.290	1.100	0.095	0.009	0.020
73/04/07	08 30		0.031	1.400	0.040	0.005K	0.015
73/05/02	12 16		0.350	1.100	0.027	0.010	0.055
73/05/10	18 30		0.176	1.260	0.034	0.014	0.050
73/06/04			0.370	1.540	0.235	0.010	0.042
73/06/18	08 20		0.200	1.320	0.094	0.058	0.095
73/07/23	13 10		0.010K	0.690	0.026	0.005K	0.035
73/07/28	08 30		0.240	2.200	0.170	0.037	0.100
73/08/28	09 30		0.023	0.900	0.042	0.007	0.045
73/09/28	10 00		0.044	0.750	0.230	0.050	

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2673C1 LS2673C1
43 52 00.0 084 32 30.0
5 MR TOBACCO RIVER
26 GLADWIN CO
T/ROSS LAKE (RESERVOIR)
GROUT RD XING
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	09 55		0.410	1.000	0.084	0.040	0.082
72/12/02	09 05		0.310	0.390	0.039	0.034	0.052
73/01/06	09 45		0.430	0.810	0.100	0.034	0.067
73/02/03	09 25		0.530	2.200	0.231	0.064	0.170
73/03/03	09 40		0.399	0.590	0.105	0.035	0.065
73/04/07	08 40		0.260	0.880	0.038	0.024	0.055
73/05/02	11 10		0.340	1.100	0.027	0.015	0.060
73/05/10	18 40		0.710	1.600	0.034	0.032	0.090
73/06/04	15 10		0.357	0.850	0.105	0.024	0.060
73/06/18	08 10		0.378	0.720	0.036	0.052	0.105
73/07/23	14 00		0.010K	0.680	0.017	0.005K	0.050
73/07/28	08 50		0.250	0.700	0.025	0.044	0.108
73/08/28	09 40		0.220	0.540	0.017	0.047	0.105
73/09/28	13 30		0.260	0.240	0.038	0.110	0.150

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

257301 CS267301
43 54 30.0 084 31 30.0
MIDDLE BR TOBACCO RIVER
26 GLADWIN CO
T/ROSS LAKE (RESERVOIR)
MCCULLOUGH RD XING
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	10 15		0.440	2.450	0.180	0.009	0.022
72/12/02	09 15		0.420	0.380	0.024	0.005K	0.009
73/02/03	09 30		0.490	1.200	0.160	0.034	0.118
73/03/03	09 50		0.600	0.740	0.092	0.015	0.055
73/04/07	08 50		0.360	0.740	0.026	0.012	0.035
73/05/02	10 00		0.350	1.100	0.027	0.015	0.060
73/05/10	17 50		1.240	1.150	0.017	0.013	0.085
73/06/04	16 00		0.420	0.480	0.154	0.018	0.075
73/06/18	07 50		0.294	0.360	0.010	0.006	0.020
73/07/23	11 10		0.010K	0.710	0.016	0.005K	0.035
73/07/28	08 55		0.260		0.012	0.007	0.025
73/08/28	09 50		0.315	0.290	0.013	0.005K	0.035
73/09/28	13 00		0.300	0.290	0.044	0.010	0.020

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2473E1 L5267 3E1
43 55 30.0 084 31 00.0
N BR TOBACCO RIVER
26 GLADWIN CO
T/ROSS LAKE (RESERVOIR)
CALHOUN RD XING
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/12/02	09 20		0.117	0.440	0.033	0.008	0.013
73/01/06	10 03		0.200	0.465	0.027	0.007	0.012
73/02/03	09 40		0.280	1.890	0.078	0.012	0.050
73/03/03	10 00		0.240	0.540	0.080	0.013	0.045
73/04/07	09 10		0.147	0.550	0.019	0.005K	0.020
73/05/02	09 10		0.350	0.440	0.040		0.068
73/05/10	19 08		0.480	0.670	0.012	0.006	0.040
73/06/03	14 20		0.360	1.320	0.300	0.013	0.040
73/06/18	07 40		0.066	0.360	0.025	0.005K	0.015
73/07/23	15 20		0.010K	0.660	0.016	0.005K	0.035
73/07/28	08 55		0.085	1.380	0.052	0.005K	0.020
73/08/28	10 00		0.019	0.580	0.006	0.006	0.015
73/09/28	12 30		0.059	0.120	0.008	0.008	0.015

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2673F1 LS2673F1
43 55 30.0 084 29 30.0
CEDAR RIVER
25 GLADWIN CO
T/ROSS LAKE (RESERVOIR)
HOWARD RD XING
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	11 15		0.163	1.800	0.194	0.010	0.027
72/12/02	10 30		0.117	0.420	0.023	0.014	0.025
73/01/06	10 30		0.330	1.030	0.115	0.014	0.033
73/02/03	09 45		0.252	4.600	0.105	0.014	0.055
73/03/03	11 00		0.250	0.310	0.056	0.011	0.025
73/04/07	10 30		0.198	0.630	0.050	0.009	0.030
73/05/02	17 30		0.350	1.200	0.040		0.078
73/05/10	17 30		0.830	0.690	0.680	0.009	0.035
73/06/04			0.520	1.340	0.350	0.015	0.100
73/06/18	09 35		0.092	0.500	0.037	0.017	0.035
73/07/23	12 40		0.026	0.645	0.011	0.005K	0.045
73/07/28	10 30		0.088	0.440	0.020	0.017	0.035
73/08/28	10 30		0.075	0.230	0.023	0.019	0.040
73/09/28	11 00		0.048	0.190	0.044	0.030	0.030

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2673F2 LS2673F2
43 59 30.0 084 30 30.0
CEDAR RIVER
26 GLADWIN CO
T/ROSS LAKE (RESERVOIR)
WILLFORD RD XING
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	11 50		0.150	0.400	0.075	0.005K	0.013
72/12/02	10 15		0.084	0.860	0.060	0.005K	0.008
73/01/06	10 30		0.320	0.445	0.035	0.006	0.020
73/02/03	09 55		0.198	0.340	0.035	0.005K	0.015
73/03/03	10 20		0.210	0.240	0.052	0.007	0.015
73/04/07	09 30		0.160	1.470	0.042	0.005K	0.025
73/05/02	11 20		0.340	1.170	0.020	0.018	0.035
73/05/10	18 10		0.790	0.450	0.011	0.005K	0.015
73/06/03	14 00		0.330	0.690	0.092	0.018	0.045
73/06/18	07 30		0.026	0.440	0.030	0.007	0.015
73/07/23	10 15		0.010K	0.660	0.017	0.005K	0.040
73/07/28	09 00		0.029	1.200	0.021	0.005K	0.010
73/08/28	10 40		0.013	0.150	0.013	0.005K	0.010
73/09/28	12 00		0.014	0.100K	0.010	0.008	0.010

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

267350 PR267350 P002071
43 13 30.0 084 29 00.0
GLADWIN
26 1.250000 MIDLAND
T/ROSS LAKE
CEDAR RIVER
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/31 73/02/28	08 00		1.160	11.500	0.160	1.260	2.880	0.600	0.680
CP(T)- 73/02/28 73/04/02	16 00 08 00		0.760	14.900	1.370	1.845	4.500	0.620	0.650
CP(T)- 73/04/02 73/04/30	16 00 08 00		1.520	9.950	0.180	1.005	3.000	0.600	0.770
CP(T)- 73/04/30 73/05/30	16 00 08 00		1.485	11.300	0.052	0.980	3.000	2.410	0.840
CP(T)- 73/05/30 73/07/05	16 00 08 00		0.860	8.600	0.294	0.880	3.300	0.820	0.820
CP(T)- 73/07/05 73/07/31	16 00 07 00		0.260	10.500	0.780	1.580	3.900	0.770	0.890
CP(T)- 73/07/31 73/08/31	16 00 08 00		0.360	9.900	0.040	0.940	2.250	0.580	0.660
CP(T)- 73/08/31 73/09/30	16 00 08 00			11.200	0.360	1.760	3.900	0.540	0.570
CP(T)- 73/09/30 73/10/31	16 00 08 00		0.180	11.500	0.063	1.000	2.700	0.420	0.560
CP(T)- 73/10/31 73/11/29	16 00 08 00		0.440	11.500	0.072	1.400	3.500	0.740	0.530
CP(T)- 73/11/29 73/12/31	16 00 08 00		0.560	17.500	1.500	1.500	4.100	0.590	0.440
CP(T)- 73/12/31 74/01/31	16 00 08 00		0.280	12.500	1.050	0.620	3.000	0.710	0.560
CP(T)- 74/01/31	16 00		0.580	8.300	0.120	0.670	4.100	1.000	0.900